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Name: Deborah A. Kelly
Signature: Deborah A. Kelly

TELEPHONE LINE INTERFACE CIRCUIT AND METHOD

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to an interface circuit for a telecommunications line, and particularly to a hybrid circuit for communicating over a telephone line.

Background of the Invention

Hybrid circuits have been used in modems or other communication devices to isolate the modem receiver from being affected by transmissions of the modem transmitter. Known hybrid circuits include a transformer circuit utilizing at least two transformers. Although somewhat effective in isolating the

modem receiver path from the modem transmitter path, the transformer hybrid circuit is expensive to implement on an integrated circuit.

A second known hybrid circuit is a resistive divider circuit implemented in a resistor bridge configuration. The resistive divider circuit, however, degrades the signal strength of the signal transmitted over the telecommunications line and itself generates an appreciable amount of thermal noise due to the presence of resistors therein, thereby providing a relatively poor signal-to-noise ratio. Consequently, for handling communication over a relative high loss line, such as a twisted pair telephone line, a resistive divider hybrid circuit is not a perfect solution.

Other attempts to separate the receive path of a modem from the transmit path thereof include the use of a filter. In order to provide a substantially complete isolation of the received signals from the transmitted signals, however, a very high order filter having a relatively high dynamic range is required. As is well known, such filters are quite expensive to implement.

Based upon the foregoing, there exists a need for a hybrid circuit for a modem or other device which effectively and economically isolates the receive path from the transmit path.

SUMMARY OF THE INVENTION

The present invention overcomes the shortcomings in prior systems and thereby satisfies a significant need for a hybrid circuit for a modem or other device having a transmitter and a receiver associated with a telecommunications line, such as a telephone line on which information is communicated in two directions using the ADSL protocol. The hybrid circuit substantially cancels signals generated by the modem transmitter from appearing at the input of the modem receiver and filters signals, such as echo signals, at unwanted frequencies so that the receiver primarily receives at its input signals transmitted from a remote device.

In particular, the hybrid circuit includes a capacitive divider which suitably scales the signals generated by the transmitter and the signals appearing on the telecommunications line so that common portions of the two scaled signals substantially cancel each other at the receiver input. In addition, the capacitive divider is configured as a filter so that signal components at unwanted frequencies are substantially filtered from appearing at the receiver input. In the event the hybrid circuit receives downlink information from a remote device along the telecommunications line using the ADSL

protocol, the capacitive divider is configured as a high pass filter.

In a preferred embodiment of the present invention, the hybrid circuit is associated with a differential pair of telecommunication lines over which information is communicated. The transmitter includes a differential output and the receiver includes a differential input. In this scenario, the hybrid circuit includes a pair of capacitive dividers, each of which is configured as a filter. In the event the hybrid circuit receives downlink information from a remote device over the telecommunications line using an ADSL protocol, each filter circuit is configured as a high pass filter. Alternatively, in the event the hybrid circuit receives uplink information from a remote device over the telecommunications line using an ADSL protocol, each filter circuit is configured as a low pass filter.

In a second preferred embodiment of the present invention, the hybrid circuit is associated with a single ended telecommunications line. Accordingly, the transmitter output and the receiver input are each single ended. The hybrid circuit in this embodiment includes a single capacitive divider configured as a filter. In use in receiving downlink information from a remote device over the telecommunications

line using ADSL, the capacitive divider forms a high pass filter. Conversely, in receiving uplink information from a remote device over an ADSL telecommunications line, the capacitive divider forms a low pass filter. The hybrid circuit is connected between the transmitter output, receiver input and the telecommunications line. An inverting amplifier is connected between the transmitter output and one terminal of the capacitive divider so as to generate a signal that, after being suitably scaled by the capacitive divider, cancels like signal components appearing on the telecommunications line.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the system and method of the present invention may be obtained by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

Figure 1 is a function block diagram of a hybrid circuit according to the present invention in association with a transmitter and receiver;

Figure 2 is a schematic diagram of a hybrid circuit according to a first embodiment of the present invention;

Figure 3 is a schematic diagram of a hybrid circuit according to a second embodiment of the present invention;

Figure 4 is a schematic diagram of a hybrid circuit according to a third embodiment of the present invention; and

Figure 5 is a schematic diagram of a hybrid circuit according to a fourth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EXEMPLARY EMBODIMENTS

Referring to Figures 1 and 2, there is shown a hybrid circuit 1 according to a preferred embodiment of the present invention. Hybrid circuit 1 is coupled to one end of a telecommunications line 2 over which information is communicated. Hybrid circuit 1 cooperates with transmitter 3 and receiver 4, each of which is coupled to telecommunications line 2. Transmitter 3 and receiver 4 respectively transmit and receive information over telecommunications line 2.

It is understood that hybrid circuit 1, transmitter 3 and receiver 4 may together form a modem or portion thereof. Alternatively, hybrid circuit 1 may be a stand-alone device.

In general terms, hybrid circuit 1 is electrically connected to transmitter 3, receiver 4 and telecommunication line 2 to substantially isolate the input of receiver 4 from signals generated by transmitter 3. Hybrid circuit 1 isolates the input of receiver 4 in part by canceling common signals

appearing at the output of transmitter 3 and on telecommunications line 2. The remaining signal, a signal transmitted over telecommunications line 2 from a remote device, is applied to the input of receiver 4 for subsequent conditioning.

According to a preferred embodiment of the present invention shown in Figure 2, hybrid circuit 1 is adapted for use with a two-wire telecommunications line 2. In this case, transmitter 3 has a differential output generated by transmitter elements 3A and 3B, and receiver 4 has a differential input that feeds receiver elements 4A and 4B. Transmitter element 3A is coupled to receiver element 4A and to telecommunications line 2A. Similarly, transmitter element 3B is coupled to receiver element 4B and to telecommunications line 2B. Transmitter elements 3A and 3B are each associated with an output resistor Rout.

In this first embodiment of the present invention, hybrid circuit 1 includes a pair of circuits. First circuit 5 is connected to a telecommunications line 2A, an output of transmitter element 3B and an input to receiver element 4A. First circuit 5 is a capacitive divider including a first capacitor 6 having a first terminal connected to telecommunications line 2A and a second terminal, a second

capacitor 7 having a first terminal connected to the output of transmitter element 3B and a second terminal that is connected to the second terminal of capacitor 6, and a pull-down device 8 connected between the input of receiver 4A and ground. The capacitance values of capacitors 6 and 7 are chosen so that common signals between the output of transmitter element 3B and signals appearing on telecommunications line 2A are scaled relative to each other so as to be substantial inversions of each other. Because the two scaled signals are added together at the input of receiver element 4A, the two scaled signals are substantially canceled thereat.

For example, in the event the output resistance Rout associated with transmitter elements 3A and 3B substantially matches the resistive load 10 of telecommunications line 2, the voltage level of the signal generated by transmitter element 3B is twice the voltage level of the related signal appearing at telecommunications line 2A. By assigning the capacitance value of C6 to be twice the capacitance value of capacitor C7, the output signal generated by transmitter element 3B is scaled by one third (1/3) at the input of receiver 4A and the corresponding signal appearing on transmission line 2A is scaled by two thirds (2/3) thereat. As can be seen, these signals cancel each other at the input of receiver element 4A. The

resulting signal appearing at the input of receiver element 4A is a portion of the differential signal transmitted to receiver 4 by a remote transmitter.

In the event information is communicated over telecommunications line 2 using a protocol in which the uplink frequency range does not completely overlap the downlink frequency range, such as the ADSL protocol, the capacitive divider of first circuit 5 is configured as a filter for filtering signal components at unwanted frequencies (uplink or downlink) from appearing at the input of receiver element 4A. For use in an ADSL modem or other similar device which transmits signals to another device on the uplink and receives transmitted signals on the downlink, first circuit 5 is configured as a high pass filter. As shown in Figure 2, pull-down device 8 is a resistor having a resistance value that, when combined with capacitors 6 and 7, substantially filters ADSL uplink signals transmitted by transmitter 3.

In a preferred embodiment of the present invention that is adapted for use with a two-wire telecommunications line 2, hybrid circuit 1 further includes a second circuit 12 which is electrically connected to telecommunications line 2B, the output of transmitter element 3A and the input of receiver element 4B. Second circuit 12 preferably mirrors first circuit 5 so as to

correspondingly scale the output of transmitter element 3A and the related signal appearing on telecommunications line 2B relative to each other. In this way, the scaled signals cancel each other at the input to receiver element 4B so that receiver element 4B only receives signals transmitted by a remote transmitting device.

Similar to first circuit 5, second circuit 12 is implemented as a capacitive divider in order to suitably scale the signals for cancellation. Second circuit 12 preferably includes capacitor 13 having a first terminal connected to telecommunications line 2B and a second terminal, and capacitor 14 having a first terminal connected to the output of transmitter element 3A and a second terminal connected to the second terminal of capacitor 13. The capacitance values of capacitors 13 and 14 are chosen based upon the ratio of the signal voltage generated by transmitter element 3A to the signal voltage appearing on telecommunications line 2B due to the signal generated by transmitter element 3A. The capacitance values for capacitors 13 and 14 are chosen so that the ratio of the capacitance value of capacitor 13 to the capacitance value of capacitor 14 is the ratio of the voltage swing of the signal appearing at the output of transmitter element 3A to the voltage swing of the corresponding signal appearing on

telecommunications line 2B. In this way, signals generated by transmitter 3A are substantially canceled at the input of receiver 4B.

In the event hybrid circuit 1 is associated with the communication of information using a protocol at which the frequency range of uplink signals does not completely overlap with the frequency range of corresponding downlink signals, the capacitive divider of second circuit 12 is configured as a filter. For a modem or other device utilizing the ADSL protocol for receiving downlink signals and transmitting uplink signals, second filter 12 is configured as a high pass filter to filter out uplink transmissions by transmitter element 3A. Resistor 15 of second circuit 12 is connected between the input of receiver element 4B and ground so as to cooperate with capacitors 13 and 14 in forming a high pass filter.

Referring to Figure 3, there is shown hybrid circuit 31 according to another preferred embodiment of the present invention for use with a single ended or one-wire telecommunications line. Hybrid circuit 31 is coupled to telecommunications line 32, the single ended output of transmitter 33, and the single ended input of receiver 34. Hybrid circuit 31 includes a capacitive divider circuit 35 for suitably scaling the output signal generated by transmitter 33

and the corresponding signal appearing on telecommunications line 32 so that they cancel each other at the input of receiver 34.

Specifically, capacitive divider circuit 35 includes a capacitor 36 having a first terminal connected to telecommunications line 32 and a second terminal, and capacitor 37 having a first terminal coupled to the output of transmitter 33 and a second terminal connected to the second terminal of capacitor 36. The capacitance values of capacitors 36 and 37 are chosen depending upon the ratio of the signal voltage generated by transmitter element 33 to the signal voltage appearing on telecommunications line 32 due to transmitter element 33. The capacitance values for capacitors 36 and 37 are chosen so that the ratio of the capacitance value of capacitor 36 to the capacitance value of capacitor 37 is the ratio of the voltage swing of the signal appearing at the output of transmitter element 33 to voltage swing of the corresponding signal voltage appearing on telecommunications line 32. In this way, signals generated by transmitter 33 are substantially canceled at the input of receiver 34.

In the event hybrid circuit 31 is associated with the communication of information using a protocol at which the frequency range of uplink signals does not completely overlap

with the frequency range of corresponding downlink signals, the capacitive divider of capacitive divider circuit 35 is configured as a filter. For a modem or other device utilizing the ADSL protocol for receiving downlink signals and transmitting uplink signals, capacitive divider circuit 35 is configured as a high pass filter to filter out uplink transmissions. Resistor 38 of capacitive divider circuit 35 is connected between the input of receiver 34 and ground so as to cooperate with capacitors 36 and 37 in forming a high pass filter.

Because hybrid circuit 31 is associated with a single ended telecommunications line 32, in order for the signals scaled by hybrid circuit 31 to cancel at the input of receiver 34, hybrid circuit 31 further includes an amplifier circuit 39 having an input connected to the output of transmitter 33 and an output connected to the first terminal of capacitor 37. Amplifier circuit 39 is configured as an inverting amplifier. Amplifier circuit 39 inverts the voltage level of the output of transmitter 33 so as to produce an inverted voltage level which, following scaling by capacitive circuit 35, cancels the corresponding signal appearing on telecommunications line 32 that itself was scaled by capacitive circuit 35. In this way,

the contribution of the signal appearing at the input of receiver 34 due to transmitter 33 is substantially minimized.

A benefit of employing reactive elements in the divider of the present hybrid circuit to scale the signals for cancellation is that, unlike circuits utilizing resistive elements to scale signals, reactive elements do not generate an appreciable amount of thermal noise. As a result, the signal-to-noise ratio of the receive path of the present modem is not adversely affected by the present hybrid circuit. Further, because the capacitive divider circuit of the present hybrid circuit is configured as a filter, any thermal noise generated by the resistive element therein is suitably filtered.

It is understood that with respect to the ADSL protocol, the receiving path for a modem or other communications device requires at least a third order filter. The filter(s) in the receiving path are normally downstream of an amplifier stage. By implementing hybrid circuit 1 as a first order high pass filter which is positioned upstream of the amplifier stage (Figure 1), the filtering that is necessary downstream of the amplifier stage advantageously requires less complexity and can be implemented as an active filter implemented on an integrated circuit instead of an off-chip passive filter implemented using discrete L-C components.

It is understood that the present invention may be associated with a modem or other device including a transmitter for transmitting downlink information and a receiver for receiving uplink information at a different frequency range from the frequency range utilized by the transmitter, such as an uplink modem using the ADSL protocol. In this case, the hybrid circuit includes at least one resistive divider that is configured as a low pass filter. Figure 4 illustrates a hybrid circuit 41 for an uplink modem or other device that communicates differential signals over telecommunications line 42 using ADSL. The primary difference between hybrid circuit 41 of Figure 4 and hybrid circuit 1 of Figure 2 is that each of first circuit 43 and second circuit 44 of hybrid circuit 41 is a resistive divider that is configured as a low pass filter via connection with a capacitor. First and second circuits being each configured as low pass filters suitably filters the higher frequency downlink transmissions by transmitter elements 45A and 45B.

Relatedly, Figure 5 illustrates a hybrid circuit 51 for an uplink modem or other device that communicates single ended signals over telecommunications line 52 using ADSL. The primary difference between hybrid circuit 51 of Figure 5 and hybrid circuit 31 of Figure 3 is that the scaling circuit 53 is a

resistive voltage divider that is configured as a low pass filter via connection with a capacitor. In this way, circuit 53 suitably filters the higher frequency downlink transmissions by transmitter element so that only uplink information transmitted by a remote device is received at the input to receiver 55.

It is understood that a higher order filter, either passive or active and either low-pass or high-pass, can be used instead of the first order filters mentioned above with respect to the preferred embodiments of the present invention. In this case, either the first capacitor or resistor of the higher order filter will be split to form a voltage divider.

It is also understood that additional wiring in the transmission line transformer can be used instead of an amplifier, or the counterphase signal tapped from the differential transmission line driver circuits (transmitter elements) to generate a counterphase voltage for subsequent signal cancellation in the hybrid circuit described above.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.